Gamma Ray Imaging for Environmental Remediation (GRIER)

EMSP Project 60141

Progress Report

March 1, 2000

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The objective of the GRIER project is to apply germanium detector systems with both high spectral resolution and good imaging capabilities to the problems of environmental remediation. Over the last year, much progress has been made. We have

1. developed and built amorphous-contact germanium detectors of increasing sophistication,
2. built and tested an array of four position-sensitive germanium detectors,
3. demonstrated spectroscopy and imaging uses with ^{235}U, and

Results from this research were presented at the EMSP's first workshop in Chicago in 1998, at the SPIE Session in July 1999, and at the IEEE Nuclear Science Symposium in November 1998 and 1999.

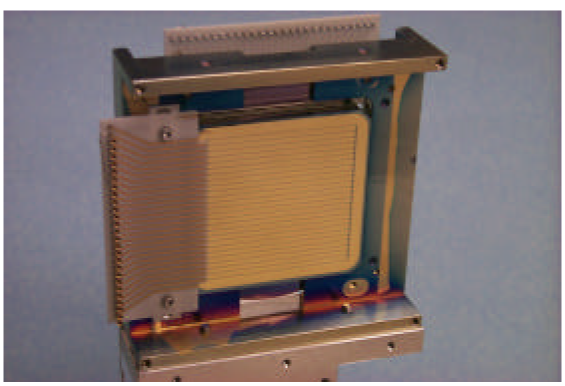

Figure 1. Full sized Ge detector with amorphous contacts. Each side has 25 strips with 2 mm pitch.

AMORPHOUS CONTACTS

The goal of the amorphous contact effort was to extend the single element (pixel) amorphous technology developed by Luke et al. (1994) to double-sided orthogonal strip detectors. Amorphous contact provides multiple advantages over the current lithium contact technology.

We have fabricated the first orthogonal strip detector with dimensions appropriate for field use. The detector has an active volume of 50 mm × 50 mm × 10 mm and has 25 × 25 strips (see Figure 1). It is currently undergoing tests. The resolution is ~12 keV FWHM, which is dominated by electronic noise. The noise was high because of the large capacitance and the non-optimal electronics used with the test cryostat.

DETECTOR ARRAY

We acquired a 2× 2 array of germanium strip detectors with conventional contact technology to build a prototype array. The individual detectors have an active volume of 50 mm × 50 mm × 10 mm and have 25 strips on each side. The full array in its cryostat is shown in Figure 2. For the first time, this array tested the possibility of daisy-chaining strips while still achieving excellent spectroscopy.

Figure 2. Array of 4 Ge detectors in cryostat. The 2 x 2 array has 2 mm position resolution.

The energy resolution is ~ 2 keV FWHM on individual strips as expected, proving

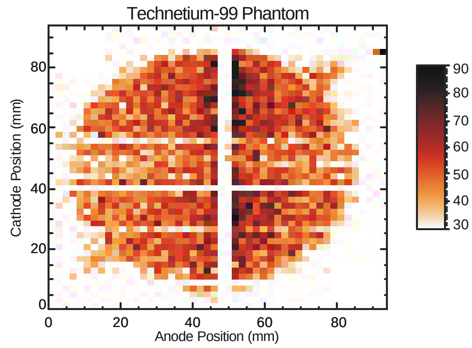

Figure 3. Image of ^{99}Tc phantom measured at 140 keV. Uniform disk of 8 cm diameter. Fill tubes are seen in upper right and lower left corners.

the possibility of daisy-chaining.

We designed and manufactured a collimator to use in conjunction with the detector array. The collimator is a parallel hole collimator. It has a two-dimensional pattern of 400 micron square holes, with a pitch of 500 micron. Since the pitch is much smaller than the strip pitch on the detector, the collimator does not have to be aligned accurately with respect to the detector.

The image of a medical phantom with a circular pattern filled with Technetium-99 is shown in Figure 3. The protrusions on the top right and bottom left of the circle are real. They are created by notches in the phantom cavity that were also filled with the radioactive Technetium. The vertical strip of low flux in the image at ~45 mm is caused by a structural support in the cryostat that blocks two of the strips.

LABORATORY DEMONSTRATIONS

Figure 4. Photograph of ^{235}U sample for imaging test. Its dimensions are ~ 2 x 3 cm.

We have started testing the 2×2 germanium array in the laboratory and have demonstrated good spectroscopy and imaging with various isotopes. As an initial test of the system with isotopes of interest to the end users, we imaged a piece of uranium (U-235). The piece, shown in Figure 4, was roughly rectangular, with dimensions of ~2 by 3 cm.

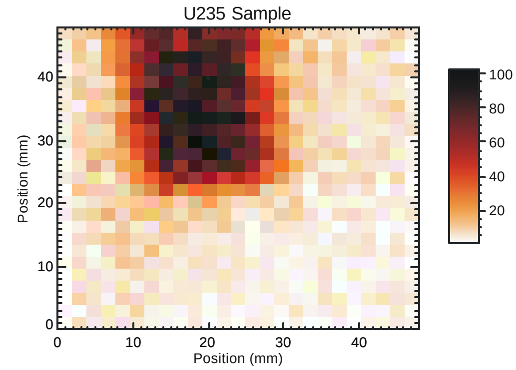

Figure 5. Image of ^{235}U sample measured in 185 keV gamma rays. Image pixels are 2 x 2 mm.

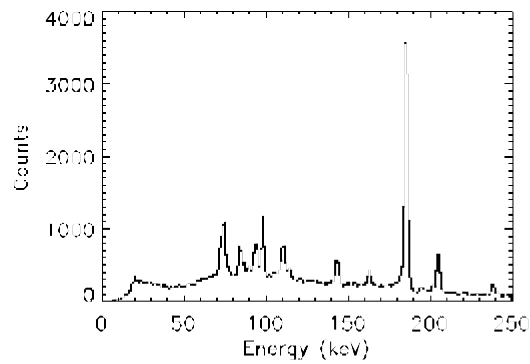

Figure 6. Complete ^{235}U spectrum measured while collecting the image in Figure. The image is in the gamma ray line at 185 keV.

The image shown in Figure 5 was obtained using the collimator and detectors described in section 0, and selecting a narrow energy window around the 185 keV line in the measured spectrum (Figure 6). The shape of the imaged object is clearly reconstructed, as expected. This energy windowing capability is essential for isolating a particular element, especially in a high background environment. A similar demonstration is also planned with a ~1 cm cube of plutonium (Pu-239). The plutonium measurements will be done with a thicker version of the collimator.

FUTURE PLANS

The remaining months of the program shall be devoted to improvements to the data acquisition and imaging systems in preparation for field test demonstrations.